Introduction to Process Simulation: Using TSUPREM4

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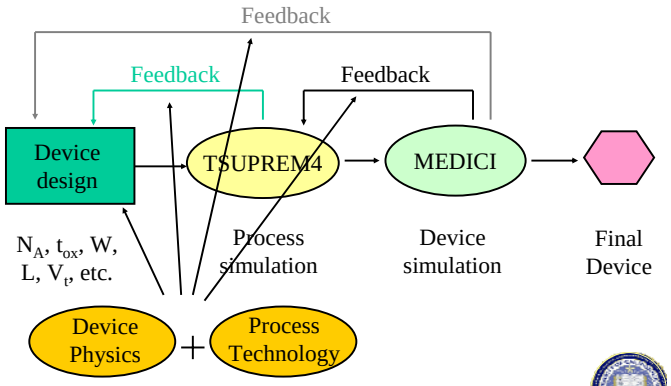
Why Simulation?

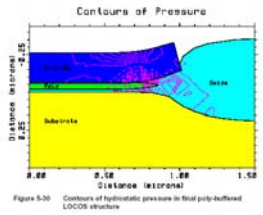
- Process (TSuprem4) and device (Medici) simulators are indispensable tools in the device community
- Simulators provide insight on processing steps, device physics, feedback in device design, and are important areas of research
- *Simulation does not replace design!!!*

Design Flow



TSUPREM-4

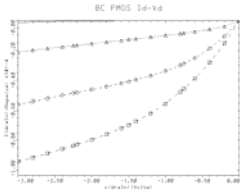
- Simulates all major process steps in 2-D
  - Deposition
  - Implant
  - Oxidation
  - Diffusion
  - Lithography
  - Etc.



- Analytical and empirical models are used to predict device cross-sections and doping profiles

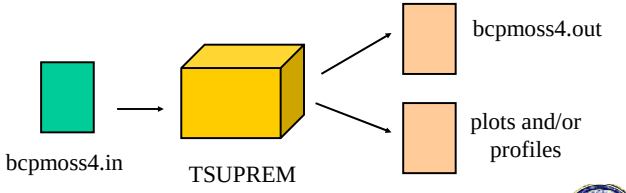
MEDICI

- Simulates electrical characteristics of a given 2-D device structure
- Takes voltage bias at each electrode
- Program solves Poisson's equation to determine the potential distribution in a device
- Applies various models for carrier transport to determine the current at each terminal



Getting started

- TSUPREM4 and MEDICI both take a text file as input
- Outputs text that is piped to the terminal
- Output includes simulation information and user-specified data (plots, cross-sections, values, etc.)

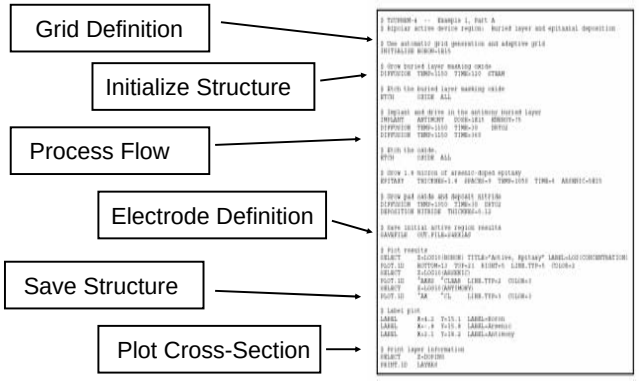


Getting started

- Use text editor to create decks (vi, emacs, pico)
- Simulators are run off UNIX workstation or PC with Hummingbird
- https://inst.eecs.berkeley.edu/cgi-bin/pub.cgi?file=tcad.help
  - /share/b/bin/tsuprem4
  - Set path = ($path /share/b/bin)
- Pop up windows:
  - setenv DISPLY [ip_address_or_computer_name]

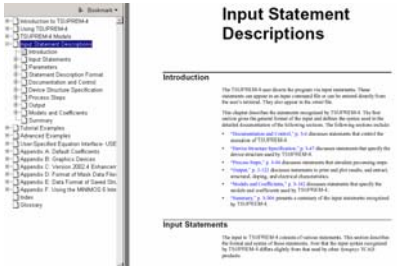
% tsuprem4 [input_file_name]

Anatomy of a TSUPREM Deck



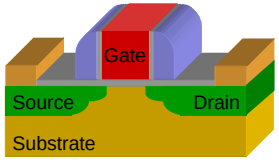
Simulator Manuals

- TSuprem and Medici Manuals are valuable resource for Input Statements and Examples
- Can find Input Statement Fields and Capabilities



Example: Basic CMOS Process

- Let's design a NMOSFET (L=0.65 um)



(From example deck s4ex4*.inp)

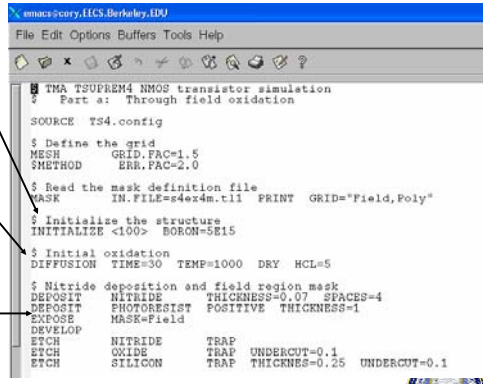
/share/instsww/synopsys/tcad/tcad-suprem-4_v2002.4/tsuprem4_2002.4.0/examples/

Example: TSUPREM Input

Start with p-type wafer

Oxidation

Define active region



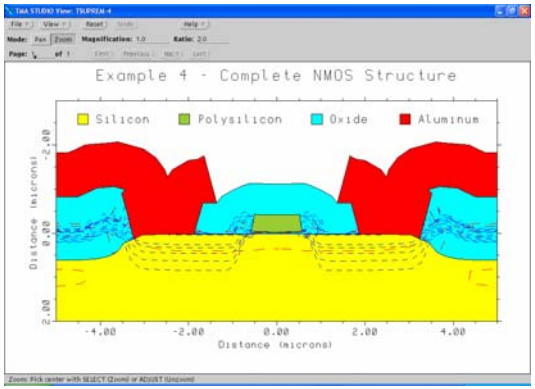
Example: TSUPREM Input

Ion implantation

Field Oxide

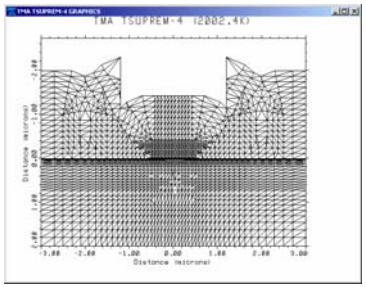
Plot initial structure

Example: TSUPREM Output



Grid Structure

- Divides the device cross-section into a 2-D array of discrete grid points
- Necessary for SUPREM to calculate solutions



- A finer grid is more accurate but also increases simulation time

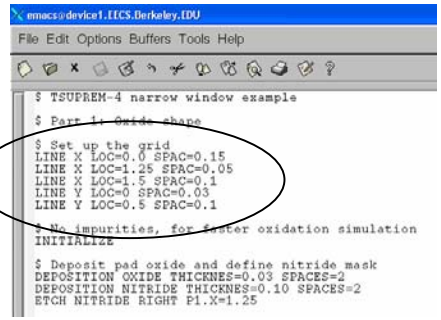
Defining the Grid

- grid.fac is the most straightforward way to vary grid density

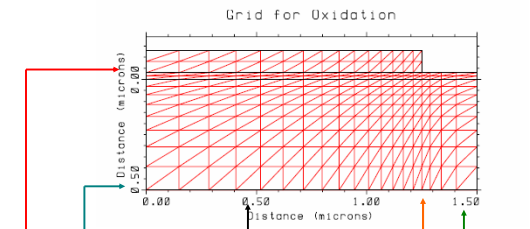
```
$ Set grid spacing and accuracy parameters
MESH        GRID.FAC=1.5
$METHOD     ERR.FAC=2.0
```

- Grid spacing can be varied spatially:
  - Line
  - Eliminate
  - Boundary
  - Region
- Grids can also be defined with saved structure files

Grid example: Local Oxidation



Grid example: Local Oxidation




```
$ Set up the grid
LINE X LOC=0.0 SPAC=0.15
LINE X LOC=1.25 SPAC=0.05
LINE X LOC=1.5 SPAC=0.1
LINE Y LOC=0 SPAC=0.03
LINE Y LOC=0.5 SPAC=0.1
```

Question: Why do we want the grid to be denser on the right side?

Other tips

- Constants make it easy to change device parameters
- Useful to plot various cross sections
- When material is deposited, grid spaces should be specified
- Have fun!!!

Questions?